Linking Sediment Exposure with Effects: Modeling Techniques
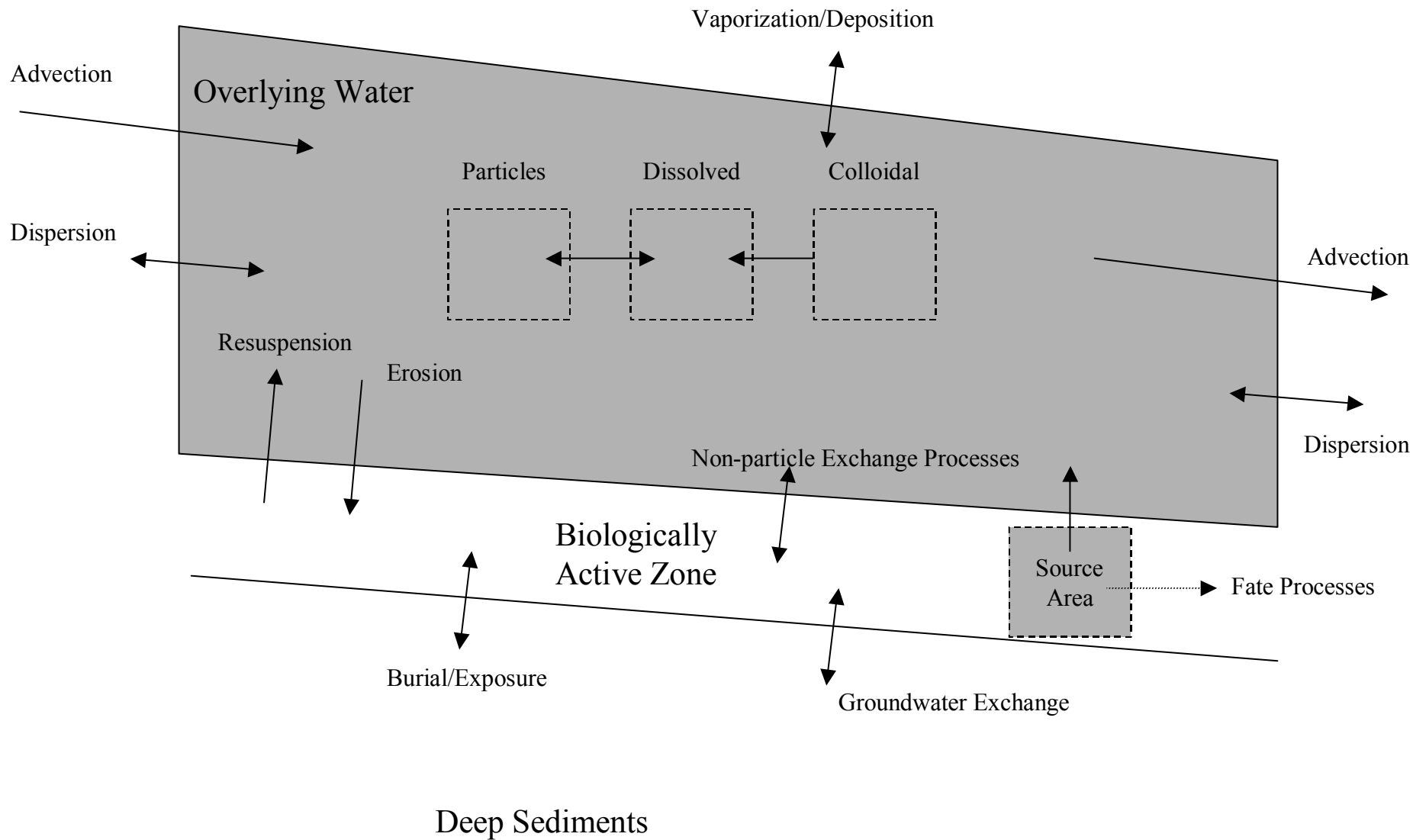
Organic Availability and Uptake

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Outline

- Modeling contaminant release and exposure
- Processes controlling exposure
- Contaminant availability
- Implications for uptake and accumulation in benthic organisms

Vaporization/Deposition

Advection

Overlying Water

Dispersion

Particles   Dissolved   Colloidal

Advection

Resuspension

Erosion

Dispersion

Non-particle Exchange Processes

Biologically
Active Zone

Source
Area

Fate Processes

Burial/Exposure

Groundwater Exchange

Deep Sediments

Processes Controlling Exposure

- Sediment resuspension
  - Sediment release
    - Granular, non-cohesive media well understood
    - Fine-grained, cohesive media
      - Model parameters related to experimental measurements
      - Remains a source of significant uncertainty
  - Contaminant release from resuspended sediment
    - Organics – largely defined by equilibrium partitioning
    - Metals – complex function of metal speciation

Processes Controlling Exposure

- Bioturbation
  - Normal life cycle activities of benthic organisms leading to sediment mixing and transport
  - Dominated by deposit feeders that ingest sediment
    - Densities up to 100,000 worms/m^2
    - Organisms may process 10-20 times their wt/day
  - Effects
    - Moves sediment and associated contaminants
    - Allows oxygen and nutrients deeper into sediments
    - Contributes to accumulation of contaminants in food chain
  - Turnover of upper layers of sediment at 0.3-30 cm/yr
  - Depth of influence 5-15 cm (90%+ of observations)
  - Estimated via movement of radionuclides of different half-lives

Processes Controlling Exposure

- Physico-chemical Processes
  - Controlled by porewater concentrations
    - Slowed significantly by sorption
  - Groundwater seepage
    - Some localized interactions always occurs
    - More important in permeable beds
    - Less important in bedrock, low permeability fine grained sediments
  - Diffusion
    - Ubiquitous
    - Very slow but may be only operative process

Contaminant Availability

- Observation
  - Locations exhibiting lower toxicity than might be expected from reversible partitioning of sediment contaminants

- Potential Cause
  - Reduced availability of contaminants
  - Metals in reduced, insoluble form
  - Organics strongly sorbed to solid phase

Reduced Availability

- Metals
  - SEM / Acid volatile sulfides (AVS)
    - < 1 Certain metals unavailable
    - > 1 Metals may or may not be available
- Organics
  - Equilibrium accumulation in lipids governed by porewater concentrations
  - Biota Sediment Accumulation Factor (BSAF)
    - Accumulation normalized by lipid content and organic carbon normalized sediment concentration
    - ~ O(1) for reversibly sorbed contaminants in benthic community
    - < 1 for desorption resistant contaminants?

Organic Desorption Resistance
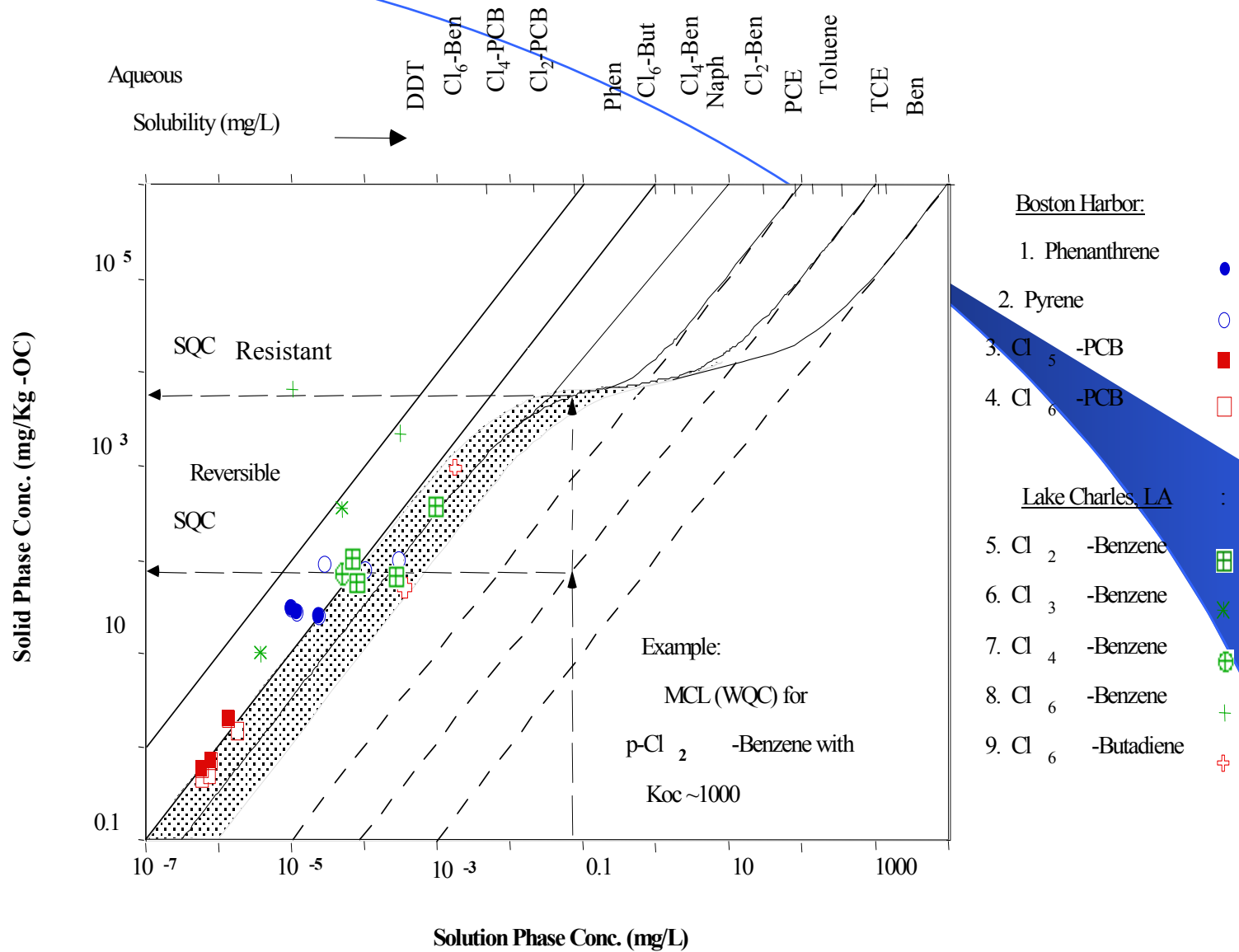
- Various Models
  - Fast, Slow desorbing compartments
    - J. Pignatello
  - Soft (young) and hard (aged) carbon
    - W. Weber
  - Natural organic carbon and soot
    - R. Luthy
  - Reversibly sorbed and sorbed w/ conformational changes
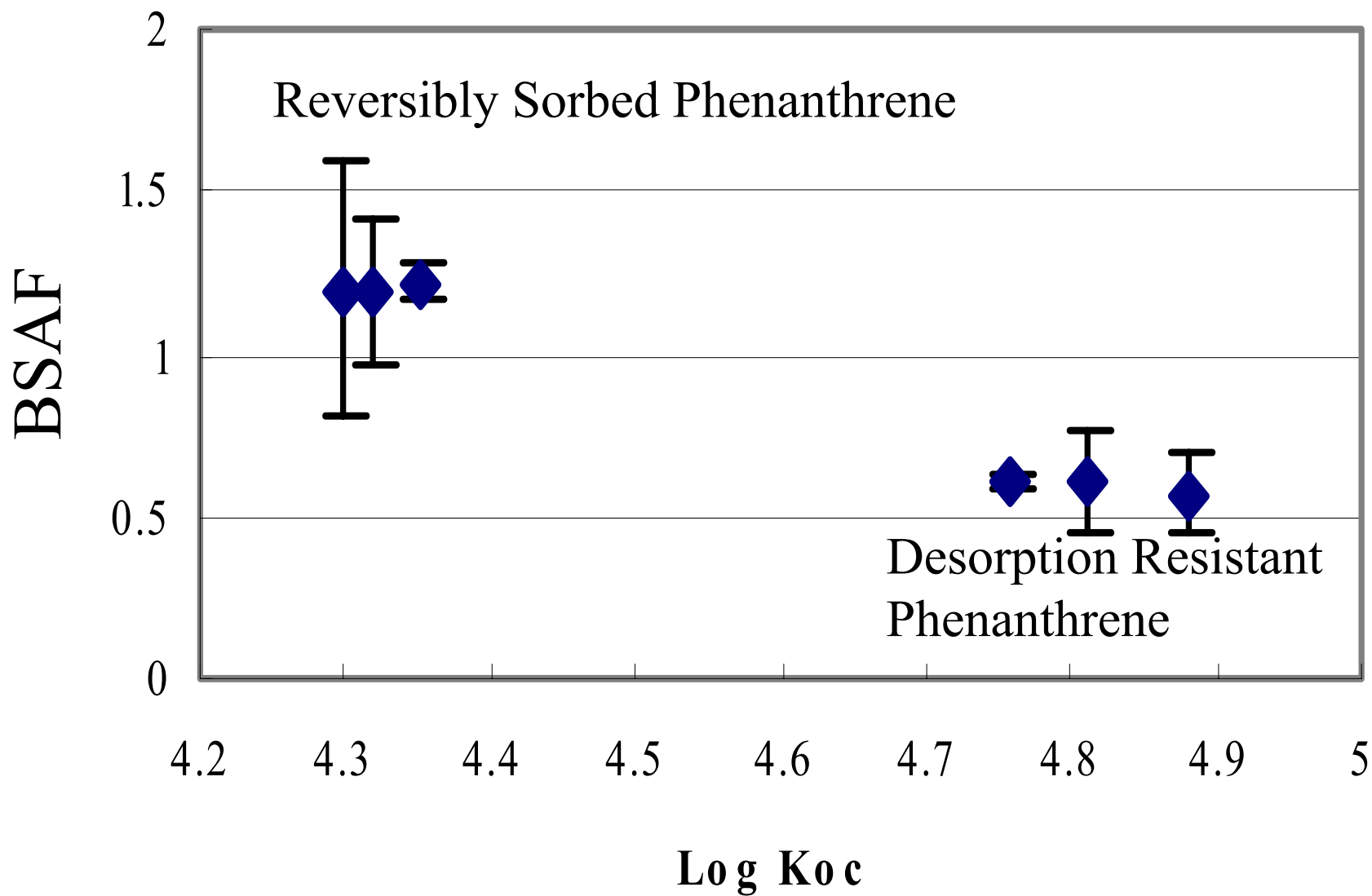   - M. Tomson
- Conclusion
  - Some contaminant desorbs rapidly and reversibly
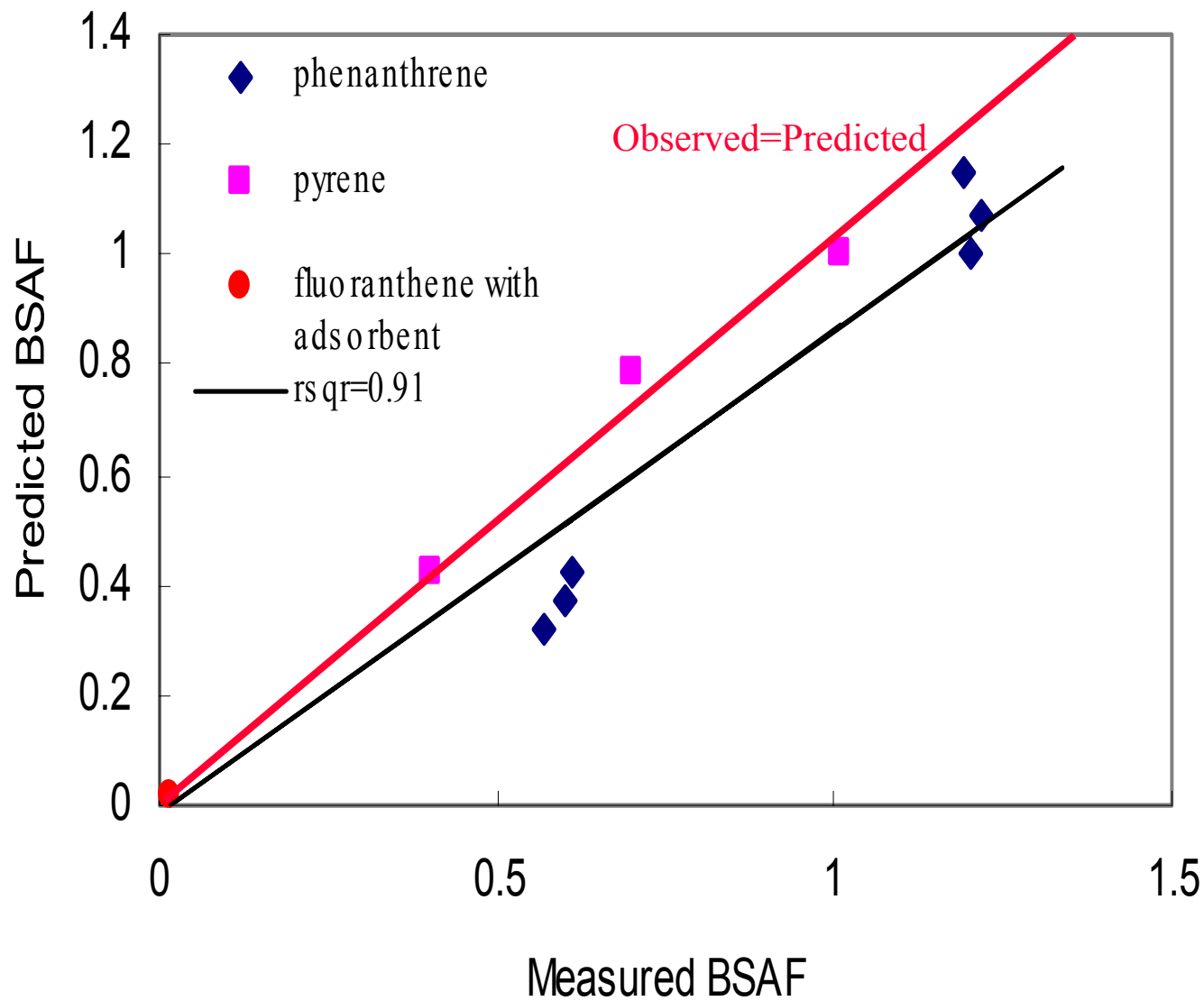 - Some contaminant desorption limited in rate or extent
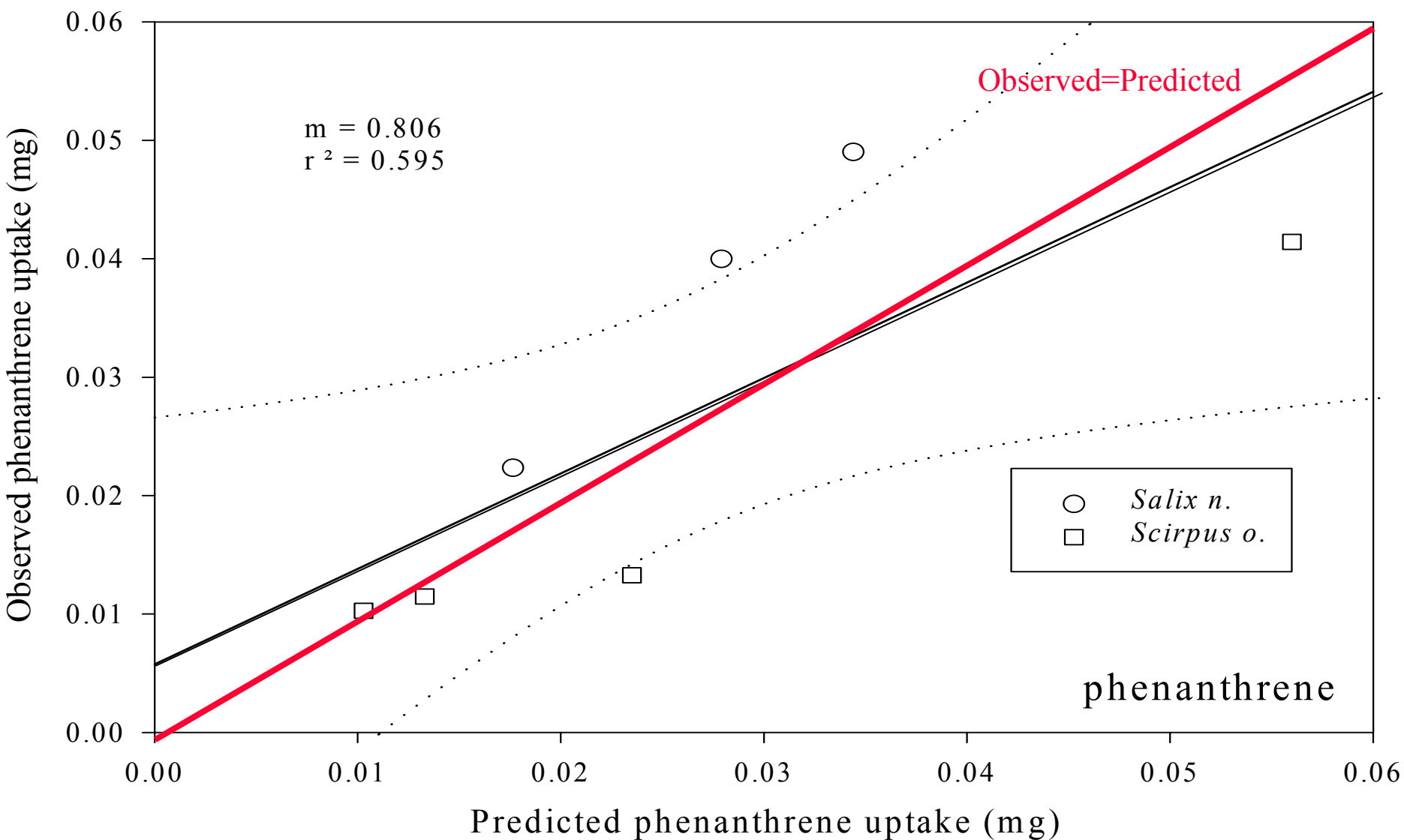
Desorption Resistant Model
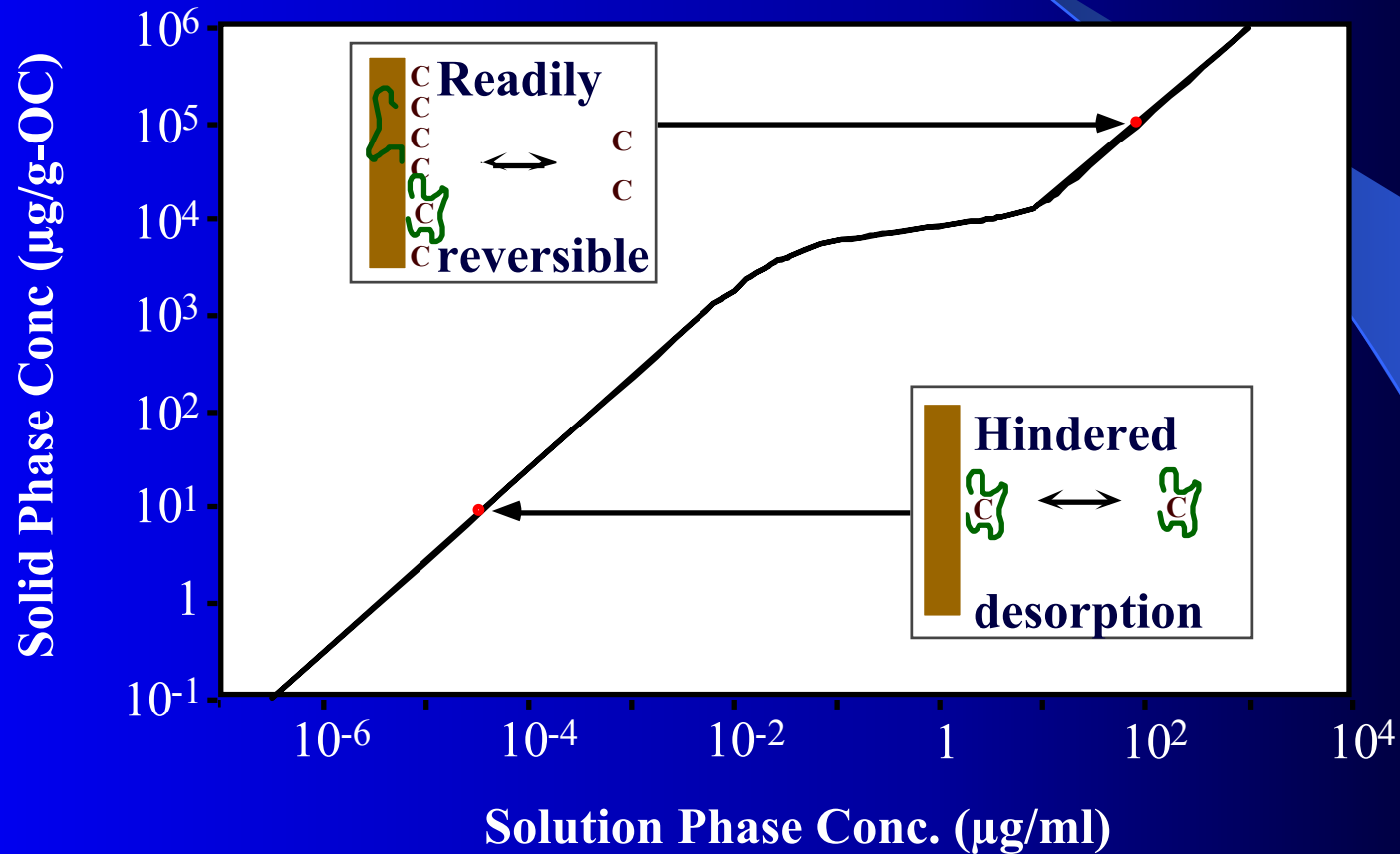
Normalized Accumulation in Oligochaetes

BSAF predicted from the effective partition coefficient versus measured BSAF

Model Uptake in Wetland Plants from Desorption Resistant Sediments

Conclusions

- Models available to assess exposure
  - Newer models incorporate first principles and parameters can be defined by reproducible independent measurements
  - Significant data requirements
- Desorption resistance
  - Reduces accumulation & uptake in plants and animals
  - Reduction apparently proportional to reduction in porewater concentrations
  - BSAF and porewater concentrations best indicator for benthic organisms